AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY 111:193–209 (2000)

Biocultural Analysis of Sex Differences in Mortality Profiles and Stress Levels in the Late Medieval Population From Nova Rača, Croatia

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KEY WORDS bioarchaeology; skeletal biology; dental pathology; Croatia

ABSTRACT Human skeletal remains of 104 individuals from the late medieval (14th–18th century) Nova Rača cemetery, in continental Croatia, are described. Historic data from the parish Book of the Dead, relevant to a period in the early 19th century, suggest that females may have been under greater stress than males. To test this hypothesis, the skeletal material is analyzed for the presence and distribution of enamel hypoplasias and cribra orbitalia. Observations are also made on the presence and pattern of dental disease, skeletal infection, trauma, osteoarthritis, vertebral degenerative changes, and Schmorl's depression frequencies.

The mortuary sample, consisting of 36 subadults and 68 adults, exhibits underrepresentation of subadults, and differential adult male/female mortality profiles. Peak female mortality is between 21–25 years, compared to peak male mortality between 31–35 years. Average adult female age at death is 29.9 years, compared to 34.1 years in adult males. Significant sex differences are present in the frequencies of enamel hypoplasia. Adult females have higher frequencies of hypoplastic teeth, and a larger number of defects in the teeth affected than in males. Subadults in the series also exhibit higher frequencies of hypoplastic teeth, and a larger number of defects in the teeth affected than in adults, documenting a relationship between enamel hypoplasia-causing stress events and reduced life expectancy. Significant sex differences are also present in dental pathology frequencies, possibly reflecting differences in resource access. Sex differences in vertebral osteoarthritis and Schmorl's depression frequencies may reflect differential activity patterns. Am J Phys Anthropol 111:193–209, 1999.

The Nova Rača archaeological site is a late medieval cemetery adjacent to the present parish church of the "Assumption of the Holy Virgin Mary." It is located approximately 75 km east of Zagreb, in the continental part of Croatia. Excavations carried out in the cemetery, from 1986–1995, revealed 104 well-preserved human skeletons. Archaeological analyses of the recovered artifacts indicate that the recovered individuals were buried between the 14th–18th centuries (Medar, 1987; Jakovljević, personal communication, 1998). Recently published historical data from the Nova Rača parish Book of the Dead, relevant to a period in the early 19th century (Jakšeković, 1990), offer a rare opportunity for a holistic, biocultural analysis of a Croatian archaeological skeletal series. The data concern the sex, cause of

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Received 11 July 1997; accepted 15 September 1999.

death, and in some instances the age of all individuals who died from 1830–1848, as diagnosed by local surgeons or county officials. With this information available, a skeletal biology research project was developed with the aim of deriving osteological information about the health, nutritional status, and lifeways of this late medieval population. The collected data include observations on demography, bone pathology, and dental disease. Together with historic data, this information is used to determine the possible presence of differential male/female mortality profiles and to identify factors which could be causing this demographic dichotomy.

Sex differences in mortality profiles are frequently seen in archaeological populations. These differences often follow the same pattern with females exhibiting higher frequencies of deaths, relative to males, during late adolescent and early adult years. Peak female mortality is typically present in this age interval, and the percentage of female deaths remains uniformly higher than that of males up to the early 30s. Such differences have been recorded in skeletal populations from various parts of the world, including, among others, the Bronze and Early Iron Age proto-Lycian population from Karataş, Turkey (Angel, 1966), prehistoric Arikara (Owsley and Bass, 1979) and Middle Woodland Hopewellian (Blakely, 1971) populations from North America, the medieval Halimba cemetery sample from Hungary (Acsádi and Nemeskéri, 1970), and medieval Croatian cemetery samples from Privlaka (Šlaus, 1996a) and Danilo and Stenjevac (Šlaus, 1996b).

As increased rates of young adult female mortality are often accompanied with high rates of neonatal mortality, the aforementioned peaks might suggest that deaths in these age groups are related to increased risk caused by complications of pregnancy and childbirth. Unfortunately, antepartum complications such as toxemia and premature rupture of membranes, and postpartum complications such as hemorrhage, hypertensive disorders, and puerperal sepsis, do not affect the skeleton, precluding this hypothesis from being tested on skeletal collections. The only evidence for childbirth-related deaths that can be seen in skeletal material is the presence of fetal remains in the abdomino-pelvic cavity of an adult female. Such events are, however, rarely documented in an archaeological context on a worldwide basis (Owsley and Bradtmiller, 1983; Acsádi and Nemeskéri, 1970). These incidents, furthermore, do not reflect female deaths during the puerperal period, as well as the long-term effects of suboptimal health caused by maternal depletion, where female health is compromised due to repeated periods of pregnancy and lactation. The role of these factors in developing differential male/female mortality profiles needs further investigation through comparative analyses of mortality distributions through time and across different geographical regions.

Ethnohistoric and biological evidence suggest, however, that other variables, both cultural and biological, contribute to differential male/female mortality profiles. There is, for instance, some evidence suggesting that Plains Indian participation in the fur trade had an especially negative effect on female health. Through comparisons of precontact and postcontact Plains Indian skeletons, Reinhard et al. (1994) showed higher levels of vertebral pathology and dental disease in postcontact female skeletons, argued by these researchers to be caused by the increased workload of women who were largely responsible for processing hides and skins. Traditional female tasks combined with labors associated with the fur trade led to more pronounced degenerative disease and dental pathology, contributing to early female deaths and perinatal mortality.

Ethnohistoric analysis of the Nova Rača population (Jakšeković, 1990) suggests that females may have been under greater stress than males. This hypothesis is based on data from the Nova Rača parish Book of the Dead. In the total sample of 3,335 deaths, recorded from 1830–1848, adult males (751) are outnumbered by adult females (1,019), yielding a sex ratio of 100:135. Medar (1987) argued that differential social status may have contributed to this demographic dichotomy. Males may have been accorded privileged status because of their role in agricultural activities, and because of their importance to the defense of this area. From

the 15th–18th centuries, Nova Rača was part of a large (8,000 km^2), frequently volatile border area formed by the Habsburg rulers to act as a buffer zone between the Ottoman Turkish Empire, and the Austro-Hungarian Empire.

If males and females did, in fact, have differential social status, females could have been experiencing greater levels of childhood stress. There is a growing body of bioarchaeological evidence which has associated childhood stress with reduced life expectancy in preindustrial populations (Cook and Buikstra, 1979; Duray, 1996; Goodman and Armelagos, 1988, 1989; Mittler and Van Gerven, 1994; Simpson et al., 1990). Undernutrition and infection impair morphological development in children, and impact adult morbidity and mortality through metabolic imprinting and impaired immune response (Barker, 1994; Henry and Ulijaszek, 1996). One hypothesis which therefore needs to be tested, is that females in Nova Rača experienced higher levels of childhood stress than males.

To test this hypothesis, skeletal material from the Nova Rača cemetery was analyzed for the presence and distribution of enamel hypoplasias and cribra orbitalia. Both of these conditions reflect childhood stress (Kreshover, 1960; Stuart-Macadam, 1985).

Observations were also made on the presence and pattern of dental disease, skeletal infection, trauma, and physical stress as evidenced in the frequencies of osteoarthritis, vertebral degenerative changes, and Schmorl's depressions in vertebral bodies. Together with historic evidence from the parish Book of the Dead, these data were analyzed to see if they supported the hypothesis of lower female social status. For instance, if males were accorded higher status because of their participation in the heavy labor necessary for agricultural activities and building military fortifications, they may have been experiencing higher frequencies of osteoarthritis and vertebral degenerative disease than females.

The Nova Rača skeletal collection is well-suited for this type of investigation. The series is characterized by excellent bone preservation, archaeological recovery was carried out meticulously, and there is more than the usually-available amount of historic data relevant to the questions addressed.

MATERIALS AND METHODS

Historic records indicate that the Nova Rača church was built in 1312 (Jakovljević, 1986). There is some evidence (Dobronić, 1984) that it may have been commissioned by the Knights Templars, a military priestly order which held land in this area during the 14th century. The cemetery surrounding the church was in use from the 14th–18th centuries. From 1986–1995, this cemetery was excavated by crews experienced in burial recovery under the direction of G. Jakovljević and M. Šlaus. The recovered skeletal material is characterized by excellent bone preservation, which allowed the recovery of all age groups, including infant and fetal skeletal remains.

Because construction activities in the 17th and 18th centuries disturbed some of the burials, detailed bone inventories were obtained for each individual. All skeletal elements were scored as complete or partial. This method provides precise bone counts by left and right side, including separate tabulation of the numbers of proximal and distal joint surfaces of all major long bones. These inventories were necessary for the pathology data analysis.

Pathological features were scored using a hierarchical approach that coded lesions descriptively, according to the predominant osteoclastic or osteoblastic response, as: 1) bone loss, 2) bone increase, or 3) bone loss and bone increase. This general classification refers to the major changes possible in living bone. Following this determination, a second, more precise designation was recorded, using descriptors that defined the nature of the lesion. For example, pathologies identified as representing bone loss were classified within several subcategories, such as 1) bone loss owing to resorptive (lytic) lesion, 2) bone loss owing to porosity (pinpoint to coalesced), 3) bone loss owing to osteoporosis or osteopenia, or 4) bone loss caused by benign cortical defect. All lesions were further coded for: 1) severity (i.e., mild, moderate, severe), 2) state (i.e., active, heal-

ing), 3) extent of involvement (i.e., localized, widespread), and 4) specific location on the bone. Changes caused by degenerative bone disease were scored for the presence, location, and severity of hypertrophic bone formation (marginal, lipping, osteophytes), porosity, and eburnation (Ortner and Putschar, 1981; Steinbock, 1976). Detailed dental inventories were also completed for each skeleton. All teeth were scored as: present, lost antemortem, lost postmortem, partially erupted, or unerupted. The presence of carious lesions was noted and scored according to location as: occlusal, buccal, lingual, interproximal, or root (at the cementoenamel junction). The presence of alveolar abscesses was also scored when present. The inventory and pathology coding procedures used in this investigation are a modified version of those developed by Owsley et al. (1987, 1991).

Data on enamel hypoplasias were collected on the permanent maxillary central incisors and canines, and on the permanent mandibular canines. The selection of these tooth categories for study was dictated by the following considerations: 1) central incisors and canines are considered to be more susceptible to stress than other teeth (Goodman and Armelagos, 1985; Goodman and Rose, 1990); 2) canines have a long developmental period, from around 4 months to 6 years (Gustafson and Koch, 1974); and 3) incisors and canines display the least amount of dental calculus, which obscures enamel in some teeth from the Nova Rača series. Only macroscopic, linear enamel defects (transverse grooves or rows of pits on the crown surface) are counted in these data. Other enamel defects, such as circular pits in deciduous dentition, hyperplastic defects, and zones of discoloration, were observed in the dental remains, but were not treated in this study.

The criteria selected for determination of sex included pelvic (Phenice, 1969) and cranial morphology (Krogman and Işcan, 1986). These criteria generally provide accurate results. From a sample of skeletons of known sex, Meindl et al. (1985) reported a 3% error rate when both the pelvis and skull were evaluated. No attempt was made to estimate the sex of subadult individuals.

Adult age at death was estimated using as many methods as possible, including ectocranial suture fusion (Meindl and Lovejoy, 1985), pubic symphysis morphology (Brooks and Suchey, 1990; Gilbert and McKern, 1973; McKern and Stewart, 1957; Todd, 1920, 1921), auricular surface morphology (Lovejoy et al., 1985), and sternal rib end changes (Işcan et al., 1984, 1985). In subadults, age at death was estimated using epiphyseal fusion, diaphyseal lengths, and dental eruption criteria (McKern and Stewart, 1957; Bass, 1987; Fazekas and Kósa, 1978; Moorrees et al., 1963).

The historic data used in the analysis came from the Nova Rača parish Book of the Dead and concerned the sex, cause of death, and in some instances the age of 3,335 individuals who died from 1830–1848 (Jakšeković, 1990). Of these data, age-at-death, most often, is not well-defined, or is missing entirely. Frequently this category was left empty or described in broad categories such as "old woman," "grandmother," or "young man." Because of the sequential chronology of Catholic sacraments (baptism, at birth; communion, between the ages of 6–8 years; and confirmation, between 13–15 years), age at death was more often recorded, or when absent could be approximated, for subadults. In most cases (2,768, or 83% of the total sample), cause of death was diagnosed by medical doctors, cited in the parish book as *testimonio medici* or *testimonio chirurgi*. County and state officials diagnosed the cause of death in 567 cases (17%). These diagnoses are cited as *testimonio seniorum pagi* or *testimonio inspectoris pagi*. There is an interesting disparity in the scope of diagnoses: county officials displayed a considerably reduced range, with *mort naturalis* (death because of natural causes) being the most frequent diagnosis, while medical doctors cited a total of 67 different causes of death, although some of them, such as *artritis* (arthritis) or *podagra* (gout), can hardly be considered lethal.

RESULTS

Cemetery demography

Skeletal remains were recovered for 104 individuals. All graves were single primary inhumations. The sample is comprised of 36

TABLE 1. Age and sex distribution in the Nova Rača skeletal series[1]

Age category (years)	Subadult		Female		Male		Total	
	N	%	N	%	N	%	N	%
Birth–1	10	27.8					10	9.6
2–5	8	22.2					8	7.7
6–10	12	33.3					12	11.5
11–15	6	16.7					6	5.8
16–20			3	9.1	2	5.6	5	4.8
21–25			12	36.4	5	14.3	17	16.4
26–30			7	21.2	5	14.3	12	11.5
31–35			4	12.1	9	25.7	13	12.5
36–40			2	6.1	7	20.0	9	8.7
41–45			2	6.1	4	11.4	6	5.8
46–50			1	3.0	1	2.9	2	1.9
51–55			1	3.0	1	2.9	2	1.9
56–60			0		0		0	
60+			1	3.0	1	2.9	2	1.9
Total	36	100.0	33	100.0	35	100.0	104	100.0
Mean age at death			x = 29.87 SD = 10.48		x = 34.06 SD = 9.65			

[1] N, number of individuals dying; %, % of individuals dying. Mean age at death is calculated using median values of each age category (e.g., 23 for the age category 21–25, and 65 for the age category 60+).

subadults and 68 adults. The youngest individual is represented by fetal remains approximately 37 weeks old. The oldest age category represented in the sample is 60+ years. The sample of adults (15 years or older) includes 35 males and 33 females. Bone preservation is good to excellent. All of the recovered skeletons contain both skull and infracranial elements, and most (94.2%) are substantially complete (missing only a few bones). Five fetal skeletons, ranging in age from 37–41 weeks old, were recovered. Four of the skeletons were buried in individual graves while one, with a gestation age of approximately 39 weeks, was recovered from the pelvic area of an adult female. The age and sex distribution of the skeletons appears in Table 1.

The underrepresentation of infants in cemetery samples is an almost ubiquitous problem. In the Nova Rača series, in spite of good bone preservation, and all efforts to identify subadult burials, there is still an obvious underrepresentation of subadults, particularly in the youngest (birth to 5 years) age category. Even so, subadult mortality is high in the analyzed sample, with 34.6% of the population dying before age 16 years. The underrepresentation of infant burials becomes apparent when these data are compared to historic records. In the Nova Rača parish Book of the Dead, mortality during the first 5 years of life (before the sacrament of communion) accounts for 32% (1,067 individuals) of all deaths in the sample. This is almost twice as high as the frequency recorded in the skeletal sample (17.3%). Subadult mortality from 6–10 years decreases in the historical sample to 10.9% (365 individuals), which is similar to the 11.5% frequency recorded in the skeletal sample, and still further to 4% (133 individuals) from 11–15 years, which is also similar to the 5.8% frequency recorded in the osteological material. The total frequency of subadult deaths in the historical sample (46.9%, or 1,565 individuals) is, however, considerably higher than that recorded in the skeletal sample (34.6%). This discrepancy may reflect random variation in small samples or differential cultural practices.

In the parish Book of the Dead, the cause of death in subadults is most often attributed to *mort naturalis* (493 individuals, or 31.5% of all subadult diagnoses). The direct translation of this term is "death due to natural causes," which for practical purposes means "cause of death unknown," since it could include a host of diagnoses. Only slightly less common, however, are the diagnoses *emaceratio* and *ex debilitate (debilitas)* (449 individuals, or 28.7% of all subadult deaths), indicating undernourishment or starvation. Variations in subadult mortality frequencies between different years offer additional historic support for the presence

of undernutrition and/or starvation in medieval Nova Rača. According to the parish Book of the Dead, subadult mortality in 1838 and 1848 accounted for 73% and 68%, respectively, of all deaths in those years. This is considerably higher than the subadult mortality frequencies recorded during the other 16 years when records were kept, which averaged 37.1% (range, 34–43%) of all deaths. High subadult mortality frequencies in 1838 and 1848 may have been the result of acute undernourishment caused by crop failures and political unrest recorded for those years in historic documents (Macan, 1992). Church records also mention periods of "great hunger and starvation" for the years 1838, 1839, and 1848 (Jakšeković, 1990).

Other factors contributing to subadult mortality are unidentifiable infectious diseases accompanied with high temperatures, diagnosed as *febris*, *febris emaceratio*, *febris consumen*, *febris cataralis*, *febris nervosa*, *inflamatio febris*, *inflamatio intestinorum*, *inflamantio cerebri* and *inflamatio viscerum* (211 individuals, or 13.5%).

The average age at death of adults over 15 years (males, 34.1; females, 29.9) is roughly comparable to other medieval Croatian populations. In the Danilo cemetery, which is dated from the 10th–16th centuries, average age at death for adult males and females was 37.2 and 31.5 years, respectively (Šlaus, 1996b), while in the Stenjevac cemetery, dated from the 11th–13th centuries, adult males lived on average 35.0 years and adult females 32.6 years (Šlaus, 1996b). In both of these samples, adult females were dying at a slightly younger age than adult males. This pattern is consistent with the sex differential of average age at death for the Nova Rača cemetery. Adult females clearly seem to be at greater risk during young adulthood. Peak female mortality is between 21–30 years (57.6% of all adult females died during this interval), with the highest mortality between 21–25 years. Males show an equally well-defined peak mortality between 31–40 years (45.7% of all adult male deaths), with the highest mortality from 31–35 years.

Demographic comparisons with historic records are not possible, as the age column in the parish Book of the Dead was generally left empty in adults, or described in very broad categories. Some individuals, however, lived to such an advanced age that it was considered important enough to be recorded. In these cases, the individuals are uniformly described as being "over 70 years in age." This description is recorded for 47 individuals (21 males and 26 females). These individuals represent 2.8% of the male sample and 2.5% of the female sample from the parish Book of the Dead, and are very similar to the frequencies recorded for males and females over 60 years old in the skeletal series (2.9% and 3.0%, respectively).

As in subadults, cause of death is most frequently attributed to *mort naturalis* (in 745 of 1,770 diagnoses, or 42.1%). This diagnosis is followed by undernourishment (*ex debilitate* 271/1,770, 15.3%), unidentifiable infectious diseases with high temperature (*febris*, *febris cataralis*, *febris colida*, *febris nervosa* 138/1,770, 7.8%), pulmonary disorders (*afectio pulmonum*, *compresio pulmonum*, *inflamatio pulmonum*, *spasmus pulmonum* (104/1,770, 5.9%), and tuberculosis (*phtisis*, *scrofulis*, *hectica* (84/1,770, 4.7%). Dysentery (*disenteria*, 27/1,770, 1.5%), apoplexy (*ex apoplexia*, 18/1,770, 1.0%), and measles (*morbili*, 10/1,770, 0.6%) also contributed to adult mortality. Childbirth complications (*mort in partu, in puerperio*) accounted for 53 deaths (5.2% of all adult female deaths). Accident-related deaths (*cancrena ex contusio roto motori* (gangrene which developed after severe contusion, recorded following a fall) *contusione cerebri* (following a fall) and *sub mersa* (drowning), were recorded in adult males, where they accounted for 1.5% of all male deaths, and in subadults, where they accounted for 2.3% of all subadult deaths.

Dental diseases

The frequencies of alveolar bone disease and carious lesions in Nova Rača adult teeth are summarized in Tables 2 and 3. The correlation of these pathologies with each other, and with their age-dependence (i.e., increasing with advancing age), requires careful consideration. The general observation that alveolar bone disease and caries frequencies are more common in males could

TABLE 2. Frequency of alveolar bone disease in Nova Rača adult dentitions[1]

Age category	Female		Male	
	A/O	%	A/O	%
Young adult	14/296	4.7	36/321	11.2
Old adult	15/86	17.4	29/161	18.0
Total	29/382	7.6	65/482	13.5

[1] A, number of tooth sockets with periodontal or periapical abscess, or antemortem tooth loss; O, number of tooth sockets observed; %, % of tooth sockets with periodontal or periapical abscess, or antemortem tooth loss; Young adult, individuals aged between 16–35 years; Old adult, individuals older than 36 years.

TABLE 3. Frequency of carious lesions in Nova Rača adult dentitions[1]

Age category	Female		Male	
	A/O	%	A/O	%
Young adult	16/298	5.4	31/270	11.5
Old adult	16/63	25.4	19/134	14.2
Total	32/361	8.9	50/404	12.4

[1] A, number of teeth with carious lesions; O, number of teeth observed; %, % of teeth with carious lesions; Young adult, individuals aged between 16–35 years; Old adult, individuals older than 36 years.

be attributed to a longer average male life span. Additional analyses were therefore conducted, controlling for age in broad categories (young adult and old adult).

Alveolar bone disease (defined by the presence of periodontal or periapical abscesses and antemortem tooth loss) is higher in males (13.5%) than in females (7.6%), with a low frequency (10.9%) overall. The difference between the adult male total and the adult female total is statistically significant ($\chi^2 = 5.64, P < 0.02$). Controlling for age, the frequency of alveolar bone disease is higher in young adult males (11.2%) than in young adult females (4.7%). These frequencies are significantly different ($\chi^2 = 6.63, P < 0.01$). The difference between old adult male (18%) and old adult female (17.4%) frequencies is not statistically significant.

The overall frequency of carious lesions in the Nova Rača series is similar to the frequency of alveolar bone disease (10.7%). The difference between the adult male total (12.4%) and the adult female total (8.9%) is not statistically significant ($\chi^2 = 1.67, P > 0.05$). Once again, however, when age is controlled, caries frequency is significantly greater in young adult males (11.5%) than in young adult females (5.4%) ($\chi^2 = 5.18, P < 0.03$). No statistical difference is present between old adult male (14.2%) and old adult female (25.4%) frequencies ($\chi^2 = 1.92, P < 0.05$).

Males also exhibit more severe carious lesions than females. A four-scale grading system was used to evaluate the severity of carious lesions: grade 1, a pit or slight fissure; grade 2, more than a pit but less than half of the surface destroyed; grade 3, more than half of the surface destroyed but not the complete crown; and grade 4, complete destruction of the tooth crown. The modal category for severity of lesions in females is grade 1 (47% of all lesions), while for males it is grade 2 (48% of all lesions). Controlling for age, the modal category for young adult males is grade 2 (61% of all lesions), and for young adult females grade 1 (75% of all lesions). In older adults, the modal category for severity of lesion in males is grade 4 (37% of all lesions), and in females grade 3 (30% of all lesions).

The distribution of carious lesions in both sexes is similar. Carious lesions are most frequently located interproximally (in 47.5% of all carious lesions in males, and in 78% of all carious lesions in females), followed by occlusal (20% in males and 13% in females) and buccal lesions (15% in males and 9% in females). Males also exhibit root lesions (17.5%), which are not present in the female sample.

The overall frequencies of adult dental pathologies are low in this sample. Analyses by controlling for age suggest that sex differences in frequencies of dental pathologies are not related to the age distribution, as there are no significant differences in the "old adult" age category. Instead, sex differences (e.g., more alveolar disease and caries in young adult males and greater severity of carious lesions in young males) imply that there may have been differential susceptibility to defects, differential access to foodstuffs, differential physiological insults, and/or differential cultural behaviors which impacted dental health.

Dental enamel hypoplasia

Dental enamel hypoplasia results from a disturbance of the enamel development in the growing deciduous or permanent tooth bud (phase of amelogenesis). The causes of

TABLE 4. Hypoplasia frequencies tabulated by tooth type and by individual [1]

	By tooth			By individual		
Tooth	N	NwLEH	%wLEH	N	NwLEH	%wLEH
Maxillary I1	118	37	31.3	73	25	34.2
Maxillary C	129	43	33.3	75	27	36.0
Mandibular C	136	48	35.3	74	27	36.5

[1] N, number of teeth observed; NwLEH, number of teeth with one or more LEH; %wLEH, % of N with one or more LEH; I, incisor; C, canine.

hypoplastic defects are commonly attributed to a variety of factors, including physiological stresses such as malnutrition, infectious disease, psychological or physical trauma, or other metabolic disruptions (Goodman et al., 1980; Goodman and Rose, 1991; Kreshover, 1960). Hypoplasias remain visible until the affected enamel is worn away through dental attrition, providing a nearly permanent record of developmental arrest during infancy and early childhood. While the development of enamel hypoplastic defects cannot be attributed to a specific disease or episode in the life of a deceased individual, studies of living children document the association between higher frequencies of hypoplastic defects and poor nutrition and low socioeconomic status (Goodman et al., 1991, 1992).

The frequencies of enamel hypoplastic defects in the three analyzed teeth categories (maxillary central incisors, maxillary canines, and mandibular canines) are shown in Table 4. Hypoplasias are most frequent in the mandibular canines: 35.3% (n = 136) exhibit one or more hypoplasia. Of the maxillary canines, 33.3% exhibit hypoplasias, and 31.3% of the maxillary central incisors have hypoplasias.

Table 4 also lists percentages of individuals with one or more hypoplasia in either the right or the left antimere of each tooth. Thus the sample size for all mandibular canines is 136, but when the data are tabulated by individual, the sample size is only 74 teeth. The "by individual" tabulation does not change the relative frequency of enamel hypoplasias per tooth type (once again, mandibular canines have the highest frequency of defects, followed by maxillary canines and maxillary central incisors), but the samples are smaller, and the resulting frequencies are slightly higher. Hypoplasia frequencies are tabulated by individual to demonstrate that no significant differences are present in the relative frequencies of hypoplasias per tooth type, regardless of the manner in which the data are presented. In poorly preserved skeletal series where individuals are incomplete even in their dental remains, it can be argued that counting all teeth, instead of one antimere per individual, may create a bias towards well-preserved individuals, as those with more teeth contribute more to the data set then those with only the right or left preserved. While in the Nova Rača assemblage this is not the case, to avoid any possibility of artificially altering frequencies, the remaining enamel hypoplasia data are presented by considering only one tooth from each tooth category per individual. Enamel defects were counted on teeth from the right side of the mouth, with teeth from the left side being substituted if the one on the right was missing.

In the analyzed sample, subadults have consistently higher frequencies of hypoplastic teeth than individuals who lived into adulthood (Table 5). Subadult frequencies are significantly higher in maxillary central incisors (76.9% compared to 25.0%; $\chi^2 = 3.94$; $P < 0.05$). In populations with abrasive diets, such a pattern might be considered an artifact of dental attrition. The older the individual is, the more dental enamel and more enamel hypoplasias are worn away. In the Nova Rača series, however, dental attrition is generally slight. The modal category for dental wear in adult dentition, according to the eight stages of wear described by Smith (1984), is stage 3 (incisors and canines are characterized by the presence of a "dentin line of distinct thickness"), and dental attrition is minimal until about age 45.

TABLE 5. Hypoplasia frequencies in Nova Rača subadults and adults[1]

	Subadults		All adults		Females		Males	
Tooth	Nw/N	%wLEH	Nw/N	%wLEH	Nw/N	%wLEH	Nw/N	%wLEH
Maxillary I1	10/13	76.9	15/60	25.0	10/29	34.5	5/31	16.1
Maxillary C	10/15	66.7	17/60	28.3	14/29	48.2	3/31	9.7
Mandibular C	9/14	64.4	18/60	30.0	14/29	48.2	4/31	12.9

[1] Nw, number of individuals with one or more LEH; N, number of individuals observed; %wLEH, % of N with one or more LEH; I, incisors; C, canines.

TABLE 6. Hypoplasia frequencies in Nova Rača adult dentition[1]

	Maxillary I1		Maxillary C		Mandibular C	
Sex/age	Nw/N	%wLEH	Nw/N	%wLEH	Nw/N	%wLEH
Female						
Young adult	9/24	37.5	13/24	54.2	13/23	56.5
Old adult	1/5	20.0	1/5	20.0	1/6	16.7
Male						
Young adult	4/21	19.0	2/21	9.5	2/19	10.5
Old adult	1/10	10.0	1/10	10.0	2/12	16.7

[1] I, incisors; C, canines; Nw, number of individuals with one or more LEH; N, number of individuals observed; %wLEH, % of N with one or more LEH; Young adult, individuals aged between 16–35 years; Old adult, individuals older than 36 years.

TABLE 7. Mean number of hypoplasias in incisors and canines[1]

	Subadults			All adults			Females			Males		
Tooth	Mean	N	S.D.	Mean	N	S.D.	Mean	N	S.D.	Mean	N	S.D.
Maxillary I1	0.92	13	0.61	0.33	60	0.62	0.44	29	0.67	0.22	31	0.55
Maxillary C	0.80	15	0.65	0.37	60	0.63	0.55	29	0.62	0.19	31	0.59
Mandibular C	0.71	14	0.59	0.42	60	0.69	0.59	29	0.67	0.26	31	0.67

[1] I, incisors; C, canines.

A breakdown of the adult sample by sex (Table 5) shows that adult females consistently have higher frequencies of hypoplastic teeth than adult males. Female hypoplasia frequencies are significantly higher in maxillary canines (48.2% compared to 9.7% in males; $\chi^2 = 4.91$; $P < 0.03$), and marginally not significant in mandibular canines (48.2% compared to 12.9% in males; $\chi^2 = 3.73$; $P < 0.06$). Controlling for age, young adult females have consistently higher frequencies of hypoplastic teeth than young adult males (Table 6). These frequencies are significantly different in maxillary canines (54.2% compared to 9.5%; $\chi^2 = 3.97$, $P < 0.05$), and marginally not significant in mandibular canines (56.5% compared to 10.5%; $\chi^2 = 3.56$; $P < 0.06$). No significant differences are present in the "old adult" age categories.

The mean number of hypoplasias per tooth follows the same pattern. When the number of defects in each tooth with hypoplasias is averaged for the different groups in the sample (Table 7), subadults have a greater number of defects per tooth than adults, and adult females have a greater number of defects per tooth than adult males.

To summarize, in the three tooth categories analyzed, the frequency of hypoplasias is significantly lower in individuals who lived until adulthood. Adults have not only a lower incidence of hypoplasia, they also have a smaller number of defects in the teeth affected than the individuals who died as subadults. These data strongly suggest that hypoplasias are related to age at death in the Nova Rača series. In the adult sample, females consistently show higher frequencies of hypoplastic teeth, and a larger number of defects in the teeth affected than males. These differences, furthermore, seem to be more pronounced in the young adult age category. With a caveat for small sample size, these findings are suggestive of greater subadult stress in females.

TABLE 8. Frequency of occurrence of cribra orbitalia in the Nova Rača series[1]

Age (years)/sex	Cribra orbitalia			Active lesions	
	O	A1	%	A2	% of A1
0–0.9	10	2	20.0	2	100.0
1–3.9	5	3	60.0	3	100.0
4–9.9	7	6	85.7	3	50.0
10–14.9	7	6	85.7	2	33.3
All subadults	29	17	58.6	10	58.8
Adult females	22	8	36.4	0	0.0
Adult males	22	4	18.2	0	0.0
All adults	44	12	27.3	0	0.0

[1] O, number of frontal bones observed; A1, number of frontal bones in which at least one orbit shows evidence of cribra orbitalia; A2, number of frontal bones in which cribra orbitalia is active at time of death.

TABLE 9. Frequency of occurrence of periosteal lesions in the Nova Rača series[1]

Sex	Periosteal lesions			Active lesions	
	O	A1	%	A2	% of A1
Subadults	36	21	58.3	18	85.7
Adult females	33	8	24.2	4	50.0
Adult males	35	4	11.4	1	25.0
Total	104	33	31.7	23	69.7

[1] O, number of individuals observed; A1, number of individuals with at least one periosteal lesion; A2, number of individuals with at least one periosteal lesion active at time of death.

Cribra orbitalia

Cribra orbitalia, sievelike lesions or pitting on the orbital roof, is considered a skeletal manifestation of genetic or iron deficiency anemia by osteologists (Huss-Ashmore et al., 1982; Mensforth et al., 1978). In the Nova Rača series, the expression of this condition ranges from very slight pitting to severe sievelike lesions with considerable diplotic expansion.

Cribra orbitalia is observed in 29 (39.7%) of the 73 crania with intact orbits. The lesion first appears at 6 months of age and increases in frequency to a maximum of 85.7% in the age categories 4–9.9 years, and 10–14.9 years (Table 8). The overall subadult frequency is 58.6%. In adults the lesion has a frequency of 27.3%. The higher lesion frequency associated with infancy and childhood is consistent with the pattern observed in other skeletal series (Cybulski, 1977; El-Najjar et al., 1976; Stuart-Macadam, 1985; Mittler and Van Gerven, 1994). Further support for the age association of the lesion is seen when a distinction is made between active and healing lesions. During the first 4 years of life, all of the individuals affected exhibit active lesions. In the 4–9.9 years age category this percentage drops to 50%, and the decline continues in the age category 10–14.9 years, during which only 33.3% of the lesions are active. After age 15, all lesions show some degree of healing.

Sex differences in healing lesion frequencies are not statistically significant. However, female lesion frequencies (36.4%) are twice as high as male frequencies (18.2%). An age breakdown of lesions shows that most of the lesions in males (3/4 or 75%) are present in individuals older than 25 years, while in females most of the lesions (5/8 or 62.5%) are in individuals aged between 16–25 years.

The underlying iron deficiency causing cribra orbitalia appears to have a huge effect on mortality patterns. There is a significant difference in mean age at death between adults who show evidence of cribra orbitalia, and adults with no evidence of the lesion. Adults with healing cribra orbitalia lesions (n = 12; mean age at death, 27.2 years) on average live 8.0 years less than adults who show no evidence of the lesion (n = 32; mean age at death, 35.2 years). This difference is significant at the 0.04 level, based on the pooled *t*-test (pooled *t*-test $t = -2.19$; df = 42; two-tailed $P = 0.034$).

Infectious diseases

Skeletal evidence for infectious disease is present in subadults and adults. In comparison to adults, subadults show less resistance to infectious disease (Table 9). Slightly less than 60% of all subadults exhibit at least one periosteal lesion on any bone. The majority of these lesions show no evidence of healing. In the analyzed sample, 50% of all subadults exhibit at least one lesion active at time of death. Four skeletons buried in individual graves are younger than birth and may have been premature stillborns. Each of these exhibits active systemic periostitis including severe, generalized, active endocranial periostitis, possibly reflecting uterine infections which may be implicated in the premature births. Similarly, the fetal remains recovered from the abdomino-pelvic cavity of an adult female also exhibit severe,

active, widespread periostitis on the endocranial surfaces of the frontal, parietal, and occipital bones, on both mandibular rami, on the left clavicle, on the right ulna, and on both femurs and tibias. Of the remaining 16 subadults with periosteal lesions, 9 (4 aged from birth to 6 months, 4 from 2–5 years, and 1 from 6–10 years) exhibit both postcranial and endocranial periostitis, presumably reflecting systemic bacterial infections. In 7 subadults (5 aged from 6–10 years, and 2 from 11–15 years), periosteal lesions are localized on the tibia and fibula.

Skeletal indications of infectious disease in adults consist primarily of elevated periosteal lesions with linear striations and pitting along the shaft of long bones, most frequently the tibia, fibula, and femur. Although some cases of localized infection were noted, the majority of lesions involved a larger area of bone, typically most of the medial surface of the tibia or a large area of bone along the linea asperea of the femur. These manifestations appear to be from nonspecific infections of presumably hematogenous origin. In 7 of the 12 adults with periostitis, the lesions are healed (3 males and 4 females), while in 5 individuals (1 male and 4 females) the lesions were active at time of death. Two cases of chronic osteomyelitis are also noted. The first, resulting from a healed fracture of the proximal right tibia, is present in an adult female, while the second, caused by a fracture to the left distal femur, is present in an adult male.

The parish Book of the Dead mentions the presence of two specific diseases in 19th century Nova Rača: tuberculosis and syphilis. Tuberculosis is diagnosed as *phtisis*, *scrofulis* or *hectica*. It accounts for 4.7% of all deaths in the adult sample (84/1,770). No mention of the disease is present in the subadult sample. Skeletal tuberculosis has been recorded in other medieval Croatian populations (Šlaus, 1993). However, there is no osteological evidence for the disease in the Nova Rača skeletal series. No erosions or lesions are noted in any of the 1,418 preserved vertebra (450 subadult, 491 adult male, and 477 adult female), and no destructive foci or periosteal remodeling is noted in any of the 872 preserved ribs (369 subadult, 271 adult male, and 232 adult female).

Venereal syphilis was probably introduced into continental Croatia by soldiers returning from the War of Austrian Succession (1740–1748) (Macan, 1992). In the Parish Book of the Dead it is diagnosed under the terms *tabes* and *tabes confesus*. It accounts for 0.6% of all deaths in the adult sample (10/1,770). No osteological evidence for either venereal or congenital syphilis is seen, however, in the skeletal material.

Sex differences in the frequencies of periosteal lesions are not statistically significant. The distribution of lesions is, however, reminiscent of the pattern observed in cribra orbitalia frequencies. Female lesion frequencies (24.2%) are more than twice as high as male frequencies (11.4%). Females also have a higher percentage of lesions active at time of death.

Trauma

Healed fractures are common in the Nova Rača skeletal series. Two individuals, both male, have multiple fractures: one with a rib and femur fracture, and one with an ulnar and metatarsal fracture. Four individuals show evidence of cranial trauma. Three males have fractures of the outer table of the cranial vault (8.6% of male crania): two are small depressions in the parietal bone, and one is a transverse fracture of both nasal bones, made with a sharp-edged instrument. A small, circular depression fracture is also present in the frontal bone of one female.

In the upper part of the body, healed midshaft fractures of the left ulna, called "parry" fractures after their most common cause, are present in two males (6.3% of male ulnae). One subadult, aged between 11–13 years, has a healed midshaft fracture of the right clavicle. In the lower limb, there is a single femoral fracture, in a male, which has healed but was complicated by extensive infection. Two healed fractures of the tibia are also noted, one in a female, that resulted in chronic osteomyelitis, and one in a male. One male has a healed fracture of the fifth metatarsal of the right foot.

There are no patterns of lesion shape or location in this sample which would suggest the presence of warfare. The predominance of fractures in males, the occurrence of two

TABLE 10. Frequency of occurrence of osteoarthritis at major joints in the Nova Rača series[1]

	Shoulder		Elbow		Hip		Knee	
	A/O	%	A/O	%	A/O	%	A/O	%
Female								
Young adult	0/14	0.0	1/14	7.1	0/18	0.0	0/11	0.0
Old adult	3/6	50.0	4/9	44.4	3/8	37.5	2/4	50.0
Total	3/20	15.0	5/23	21.7	3/26	11.5	2/15	13.3
Male								
Young adult	4/15	26.7	8/22	36.4	4/24	16.7	1/24	4.2
Old adult	2/8	25.0	3/10	30.0	6/9	66.7	6/9	66.7
Total	6/23	26.1	11/32	34.4	10/33	30.3	7/33	21.2

[1] A, number of joints affected with osteoarthritis. Osteoarthritis was scored as present if at least one joint element showed evidence of osteoarthritic change. O, number of joints observed. A joint was scored as present if at least one joint element was completely present, or if two or three elements were partially present. Young adult, individuals aged between 16–35 years; Old adult, individuals older than 36 years.

midshaft ulna fractures, the cutting injury to the face of one individual, and fractures on the outer table of the cranial vault are, however, consistent with the occurrence of interpersonal violence and some degree of physical risk.

Physical stress

Several skeletal features are used to evaluate physical stress in the Nova Rača series. These features are: degenerative osteoarthritis in major joints, vertebral degenerative changes, and the occurrence and frequency of Schmorl's depressions in vertebral bodies.

Degenerative osteoarthritis is characterized by the progressive formation of osteophytes around the edges of an articular joint surface. In advanced cases the normally smooth articular surface develops ossific nodules, porosis, or eburnation. These changes are associated with the wear and tear of everyday activities and are distinguished from traumatic arthritis, which is caused by disruption of the biomechanical functioning of a joint. Each articular surface of the four major joints in the skeleton was scored for degenerative osteoarthritis on a mild, moderate, and severe scale. Osteoarthritis frequencies in the series are summarized in Table 10.

Most of the cases reported reflect mild or moderate degrees of osteoarthritis. Severe osteoarthritis is rare, with only two observations of eburnation, both involving males, and both located on the distal, lateral femoral condyles. Of the four major joints in the skeleton, osteoarthritis is most frequently recorded in the elbow. In all four joints osteoarthritis is more common in males than in females, although none of the differences is statistically significant. As the observed differences may reflect older age-at-death in males, the sample was divided into a young adult (16–35 years) and old adult (36+ years) group. Controlling for age, young adult male frequencies are higher in all four joints than young adult female frequencies, although once again, none of the differences is statistically significant.

Degenerative changes in Nova Rača spinal columns were assessed in the vertebral bodies (osteophytosis and osteoporosis of centra) and the articular surfaces of the posterior elements (osteoarthritis of facets). The overall frequency of vertebral osteoarthritis in the sample is 11.6% (49/422) (Table 11). Comparing the different regions of the spine, the greatest involvement occurs in the thoracic region (30/179; 16.8%), followed by the cervical (17/141; 12.0%) and lumbar (2/102; 1.9%) regions. For males of all ages, total male vertebral osteoarthritis frequency (16.7%) is considerably higher than for females (5.6%). This difference is statistically significant ($\chi^2 = 9.12$; $P < 0.01$). The difference between cervical spine osteoarthritis frequencies in males (19.7%) and females (4.3%) is also statistically significant ($\chi^2 = 5.02$; $P < 0.03$). Controlling for age, total vertebral osteoarthritis frequency is significantly greater in young adult males (10.6%) than in young adult females (0.8%) ($\chi^2 = 8.34$; $P < 0.01$). The most pronounced differences are in the thoracic region, where 20% of young adult male vertebrae show some degree of vertebral osteoarthritis, compared to none in the young adult female sample.

TABLE 11. Frequency of occurrence of vertebral osteoarthritis in the Nova Rača series[1]

	Cervical		Thoracic		Lumbar		Total	
	A/O	%	A/O	%	A/O	%	A/O	%
Female								
Young adult	1/48	2.0	0/43	0.0	0/31	0.0	1/122	0.8
Old adult	2/22	9.0	7/35	20.0	1/16	6.3	10/73	13.7
Total	3/70	4.3	7/78	9.0	1/47	2.1	11/195	5.6
Male								
Young adult	2/44	4.5	14/70	20.0	0/37	0.0	16/151	10.6
Old adult	12/27	44.4	9/31	29.0	1/18	5.5	22/76	28.9
Total	14/71	19.7	23/101	22.8	1/55	1.8	38/227	16.7

[1] A, number of vertebrae affected with osteoarthritis or osteophytosis; O, number of vertebrae observed; Young adult, individuals aged between 16–35 years; Old adult, individuals older than 36 years.

This difference is also statistically significant ($\chi^2 = 6.44$; $P < 0.02$). No statistically significant differences are present between old adult males and old adult females.

Schmorl's depressions are lesions which result from herniation and displacement of intervertebral disc tissue into the adjacent vertebral body. The presence of Schmorl's depressions can be idiopathic, or related to a variety of causes including certain diseases and congenital factors that produce a weakening of the subchondral bone and a disruption of the cartilaginous end-plate, and strong compression caused by traumatic injury. However, Schmorl's depressions, according to Schmorl and Junghanns (1971), are most commonly caused by degenerative changes associated with ordinary stress on the vertebral column. "The origin, progression and symptoms of vertebral disk prolapse . . . are influenced decisively by everyday demands of life. Fatigue damage, similar to fatigue fractures in the bone, can be produced in disk tissue when the demand surpasses the functional ability" (Schmorl and Junghanns, 1971, p 175). The frequencies of Schmorl's depressions in the Nova Rača series are summarized in Table 12.

The overall frequency of Schmorl's depressions in the sample is 15.6% (44/281). Schmorl's depressions are more common in thoracic (31/179; 17.3%) than in lumbar (13/102; 12.7%) vertebrae. Schmorl's depressions are considerably more frequent in males (21.1%) than in females (8.8%). This difference is statistically significant ($\chi^2 = 5.16$; $P < 0.03$), as is the difference between Schmorl's depression frequencies in thoracic vertebrae (male = 25.7%, female = 6.4%; $\chi^2 = 7.21$; $P < 0.01$). Controlling for age, total Schmorl's depression frequency is significantly greater in young adult males (16.8%) than in young adult females (4.0%) ($\chi^2 = 4.57$; $P < 0.04$). The frequency of Schmorl's depressions in young adult male thoracic vertebrae (21.4%) is also significantly higher than the frequency in young adult female thoracic vertebrae (2.3%) ($\chi^2 = 4.97$; $P < 0.03$). No statistically significant differences are present between old adult males and old adult females.

TABLE 12. Frequency of occurrence of Schmorl's depressions in the Nova Rača series[1]

	Thoracic		Lumbar		Total	
	A/O	%	A/O	%	A/O	%
Female						
Young adult	1/43	2.3	2/31	6.4	3/74	4.0
Old adult	4/35	11.4	4/16	25.0	8/51	15.7
Total	5/78	6.4	6/47	12.7	11/125	8.8
Male						
Young adult	15/70	21.4	3/37	8.1	18/107	16.8
Old adult	11/31	35.5	4/18	22.2	15/49	30.6
Total	26/101	25.7	7/55	12.7	33/156	21.1

[1] A, number of vertebrae with Schmorl's depressions; O, number of vertebrae observed; Young adult, individuals aged between 16–35 years; Old adult, individuals older than 36 years.

In the Nova Rača skeletal series, statistically significant sex differences are present in vertebral osteoarthritis, and Schmorl's depression frequencies. As there are no significant differences between older adults, these differences appear not to be related to the age distribution. Higher frequencies of vertebral osteoarthritis and Schmorl's depressions in young adult males may therefore reflect differences in activity patterns.

DISCUSSION

Analysis of the skeletal sample from Nova Rača and comparisons with historic records

from the parish Book of the Dead offer a rare insight into the biological history of late medieval Croatia. This is an important period of time characterized by numerous changes (political, social, and economic) that had a profound impact on human welfare. On the political front, this period is characterized by the emergence, and after the battle of Sisak in 1593, the gradual decline in power of the Ottoman Turkish Empire, which organized regular raiding expeditions into Croatia, and as far north as Vienna, from the 15th–17th centuries. In social and economic terms, this period is characterized by the gradual dissolution of the feudal serf system, leading to the abolishment of serfdom in 1848, and by emerging capitalism. Although of marginally significant size for statistical analysis, the data presented above represent all of the osteological evidence currently available for this period. Conclusions and interpretations derived from this sample are open to revision when larger and better documented samples become available.

This study demonstrates that adult females from the Nova Rača skeletal series experienced more frequent events of hypoplasia-causing stress than adult males. Significantly different frequencies of hypoplastic defects are present in maxillary canines. Females also have a higher mean number of hypoplasias per tooth than males.

Besides the sex difference in the frequency of hypoplasias, there is also a significant difference in hypoplasia frequencies between subadults and individuals who lived until adulthood. Adults have a lower incidence of hypoplasia and a smaller number of defects in the teeth affected than individuals who died as subadults. Similar patterns have been reported by other researchers in different populations (Cook and Buikstra, 1979; Duray, 1996; Stodder, 1997). These data strongly suggest that hypoplasias are related to decreased life expectancy.

Cribra orbitalia frequencies show a similar, although not statistically significant pattern. The frequency of healed cribra orbitalia lesions in adult females is 36.4%, compared to 18.2% in adult males. The underlying iron deficiency anemia causing the development of cribra orbitalia appears to have had a significant effect on age at death. In the analyzed sample, adults with healing cribra orbitalia lesions have an 8 years shorter average life span than adults with no evidence of the disease.

Together, the cribra orbitalia and enamel hypoplasia data strongly suggest that females in Nova Rača experienced greater subadult stress than males, and that this stress, possibly through the synergistic effect of physiological stressors and impaired immune function, significantly affected female mortality. This hypothesis is supported by the mortality profiles of adult males and females in the skeletal series. However, the degree to which possible differences in social status contributed to higher subadult stress in females remains questionable.

Grave goods are rare in Nova Rača burials, so we do not have an index of social status based on artifactual accompaniment. Osteological data do, however, suggest differential male/female activity patterns and, possibly, differential access to food resources.

Concerning the latter, males in the Nova Rača series have more caries and more alveolar bone disease than females. Analyses controlling for age show that sex differences are not related to the age distribution. These differences, therefore, may be the result of differential access to foodstuffs, differential susceptibility to dental disease, differential physiological insults, or differential cultural behaviors which impact dental health. I would argue that differential access to foodstuffs is the most probable explanation. There is no reason to suspect differential susceptibility to dental disease in young males. There is also no evidence of any type of cultural behavior that could affect dental health (e.g., dental modification, interproximal grooves, the use of different plants for therapeutic or palliative treatment) in the Nova Rača dental remains. Young adult females have higher frequencies of enamel hypoplastic defects, but these differences are located in the anterior dentition (incisors and canines), while carious lesions and periodontal or periapical abscesses in the young adult age group are located almost exclusively in the posterior dentition (premolars and molars).

Historic records show that adequate nutrition was frequently a problem in Nova Rača. Available evidence indicates that the Nova Rača population was intensely agricultural and dependent on the yearly crop for its survival (Jakovljević, 1988). High taxes imposed by local feudal barons significantly reduced the availability of food and led to uprisings that were brutally suppressed. Two uprisings were particularly widespread and violent. The first occurred in 1573 in the Stubica region, approximately 50 km west of Nova Rača, and caused extensive destruction and the deaths of at least 4,000 individuals (Čečuk, 1960). The second occurred in 1755 in Križevci, only 25 km west of Nova Rača. This uprising was so violent that a special committee was set up by the empress Marie Theresa to investigate the reasons for the revolt. The committee reported that the main reasons for the uprising were high and significantly increased taxes collected in produce (primarily livestock, wheat, and wine) and increased demands for free labor in the landowners' fields (Karaman, 1962). Another limitation on the availability of food resources were Turkish raiding parties, which effectively blocked commerce between northern and southern Croatia, and represented a constant danger to the inhabitants of Nova Rača. There is historic evidence for several such excursions, including one which occurred in 1540 that resulted in the massacre of over 40 inhabitants of Nova Rača by Turkish raiders (Medar, 1987). Poor nutrition continued to be a problem in the 19th century. In the parish Book of the Dead, starvation is the leading identifiable cause of death, responsible for 21.6% (720/3,335) of all deaths recorded from 1830–1848. If higher frequencies of carious lesions and alveolar bone disease in young adult males from the Nova Rača skeletal series are, indeed, the result of more access to frequently limited food resources, this is suggestive of higher male social status.

Medar (1987) speculated that possible differences in social status may be the result of male participation in the defense, construction, and maintenance of military installations, and in agricultural activities. Nova Rača is situated in the center of what was a large, crescent-shaped border area separating continental Croatia (at that time part of the Austrian Habsburg Kingdom) from the Ottoman Turkish Empire. Males from 16–60 years old constructed and maintained military facilities and participated in the defense of the border. As compensation they were granted lots of land, and (in theory) were exempt from taxation by local barons. In practice there was continual tension between the defenders and the barons, which frequently erupted in revolts as described above.

The high frequencies of vertebral osteoarthritis and Schmorl's depressions in males from the Nova Rača skeletal series are consistent with heavy physical strain on the vertebral column. Due to the nonspecific nature of these indicators, etiological determinations of specific activities are inappropriate. What is clear from the skeletal data is that males in the analyzed sample have significantly higher frequencies of vertebral osteoarthritis and Schmorl's depressions than females, and that this difference is not age-related. These data are suggestive of higher levels of physical stress in young adult males, and differential male/female activity patterns.

Males in the skeletal series also have higher frequencies of skeletal trauma than females, although none of the lesions were lethal. However, individuals who died in military campaigns may have been buried at the site of their death and not in the Nova Rača cemetery.

Historic data from the parish Book of the Dead indicate poor nutrition and high subadult mortality. Of interest is the relatively small female mortality due to complications of childbirth. Female mortality during childbirth and an undefined postpartum period, diagnosed as *mort in partu (in puerperio)*, is responsible for 5.2% of adult female deaths.

Correlating skeletal changes with data from the parish Book of the Dead proved less rewarding than was hoped. Most of the diagnoses cited cannot be related to specific diseases. Furthermore, the diagnoses that can be recognized, i.e., *apoplexia* (apoplexy), *disenteria* (dysentery), *inflamatio pulmonum* (pneumonia), and *morbili* (measles), tend not to affect bone tissue. Skeletal evidence for two diseases which can be recog-

nized in skeletal remains (tuberculosis and syphilis) is not present in the skeletal sample.

CONCLUSIONS

Examination of the Nova Rača skeletal series provides a rare opportunity to address questions concerning health, disease, nutrition, and cause of death in medieval Croatia. There is very little comparable bioarchaeological information available for medieval Croatian populations. Hence, the biological and pathological information collected for Nova Rača provides an important database for future historic, demographic, and osteological research. Significant sex differences in the frequencies of enamel hypoplasia suggest higher subadult stress in females. This stress may have affected female mortality, as evidenced in the mortality profiles of adults where females have a 4.2 years shorter mean life span than males. Significant sex differences in vertebral osteoarthritis, Schmorl's depressions, and dental pathology frequencies may reflect differences in activity patterns and resource access, perhaps related to differences in social status. Continued research and comparisons between Nova Rača and other Croatian skeletal series are necessary to illuminate the possible causes of these differences.

ACKNOWLEDGMENTS

I express my appreciation to the two anonymous reviewers whose comments greatly improved this paper.

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